



Main Valve Actuator System for Cryogenic Rockets

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Executive Summary

The rocket team had encountered a problem at the latest test fire such that the liquid oxygen (LOX) line had frozen over causing the liquid natural gas (LNG) to combust with little oxygen resulting in little propulsion. The UCI Rocket project requires a redesign of the main valve actuators to ensure the success of both the LOX and LNG propellant lines. The UCIRP Main Valve Actuation System (MVAS) team has designed a valve actuation system that can open and close both propellant lines simultaneously. The main objective of the project is to develop and prototype a lightweight valve system that ensures actuation of both valves under the limiting conditions.



Cold Brew where the design will be mounted to and tested on.



Current Rocket Render where design will be mounted to

Objectives

- Develop a new actuation system that contain two mechanically linked valves that will actuate simultaneously with the use of one actuator
- System can withstand 600 psi
- System operates in cryogenic conditions
- Weight of the system is lighter than the current system weight of 34 lbs
- Both valves actuate within 0.5 seconds of each other
- Fits within the vertical height of the rocket as well as its diameter

Prior Design and Work

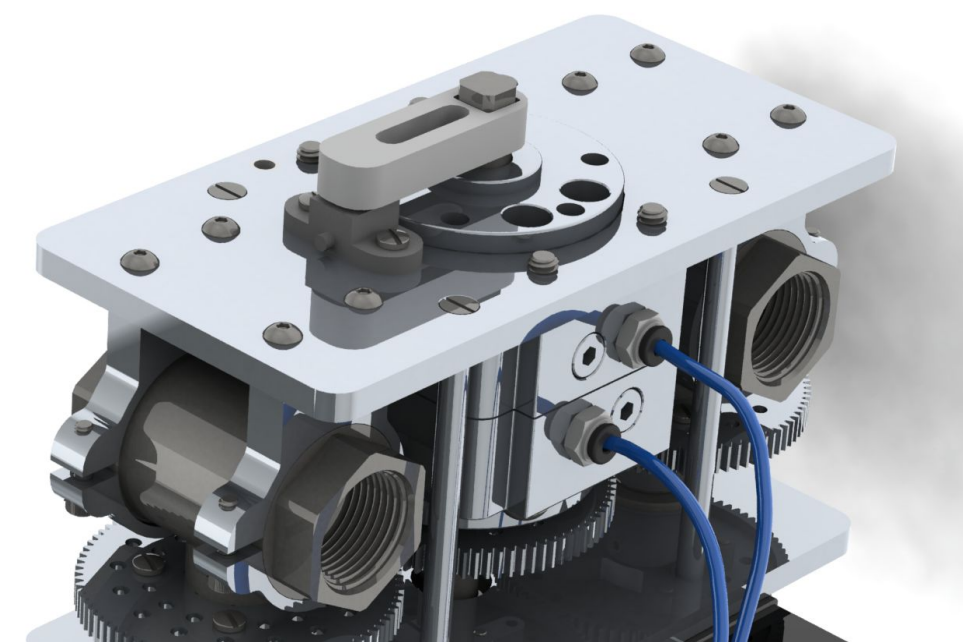
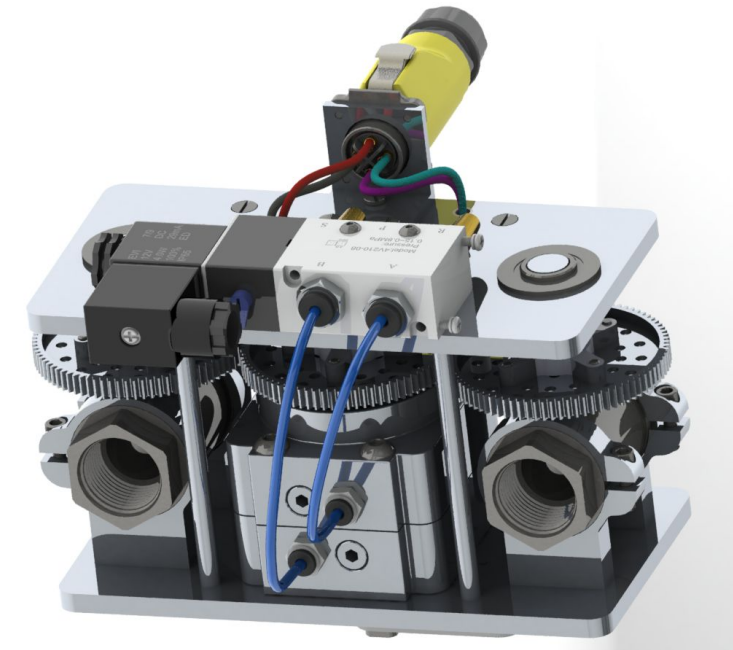
- Solenoid valve design that was individually actuated
 - oxygen line froze over, leading to non simultaneous actuation causing necessary redesign
- Matlab code to calculate pressure loss through pipes and fittings provided by the Rocket Team
- Piping and Instrumentation diagram of the current plumbing system
- Grab Cad of current rocket system
 - used to ensure that the design fits within the parameters of the rocket
 - To develop mounting options on the rocket for the design



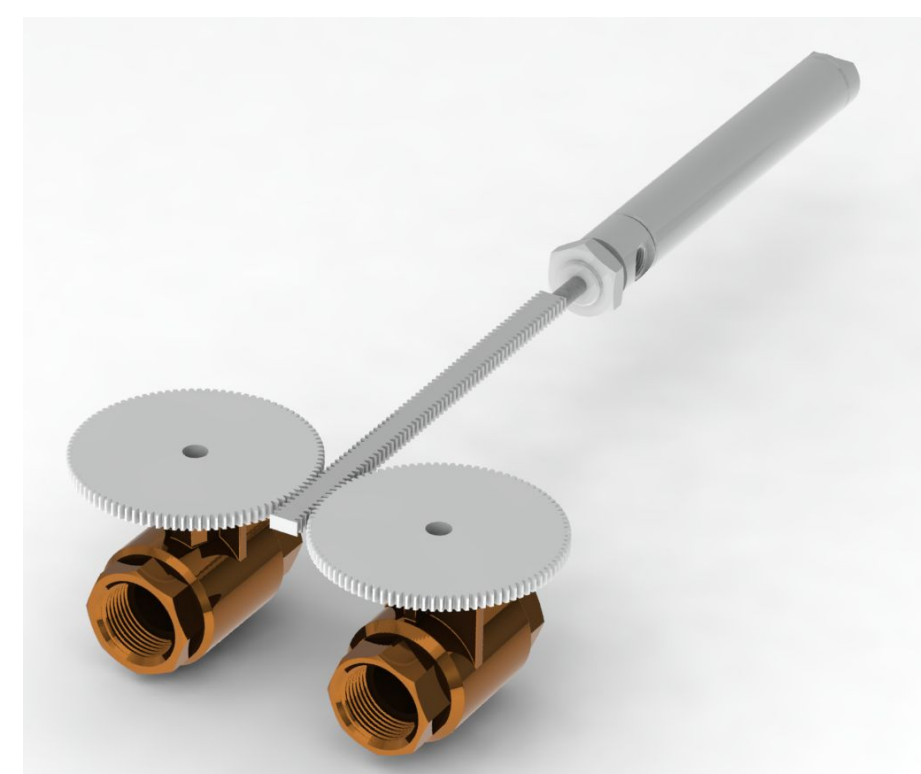
Previous solenoid valve design with the top valve being the main valve

Design Concepts

- Rotary Vane Actuator Design



- Rack and Pinion Linear Pneumatic Actuator Design

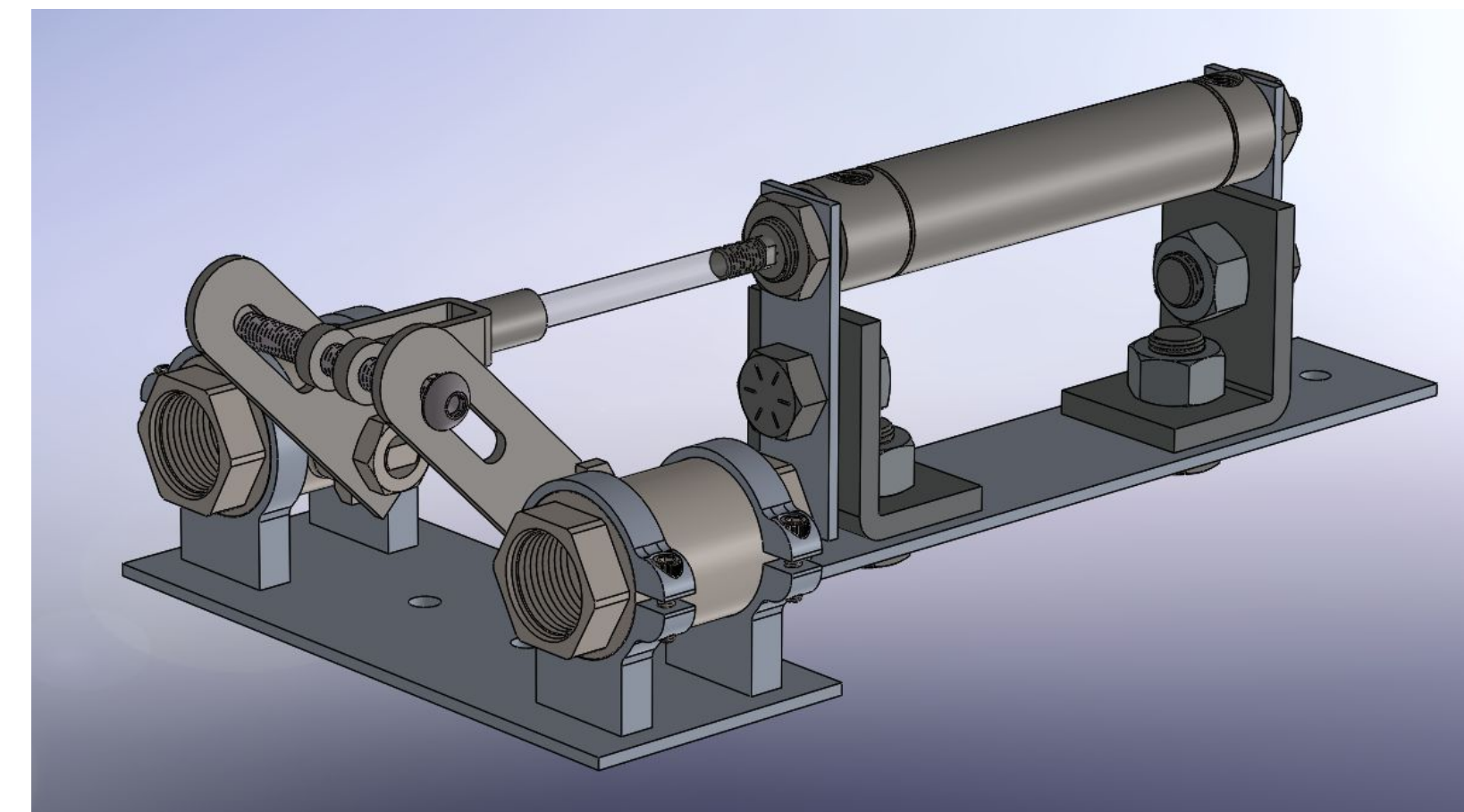


- Bar Linkage Linear Pneumatic Actuator Design



Final Design

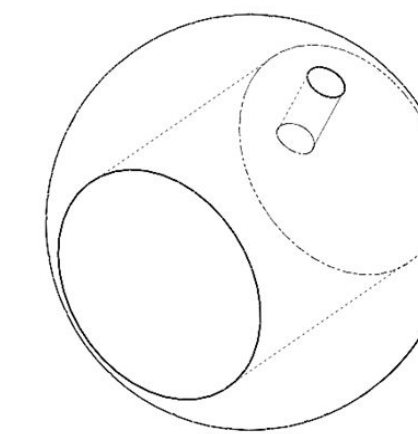
- Standard ball valves will be modified to Uses a scotch yoke-style mechanism to convert the linear motion of the actuator to rotational motion for the ball valves.
- Flat mounting plate for easy incorporation to vertical test fire and preliminary test rocket.
- All OTS components can be bought off of McMaster-Carr.
- MTS components will be CNC milled.
- Manufactured components will be mostly aluminium to reduce weight.



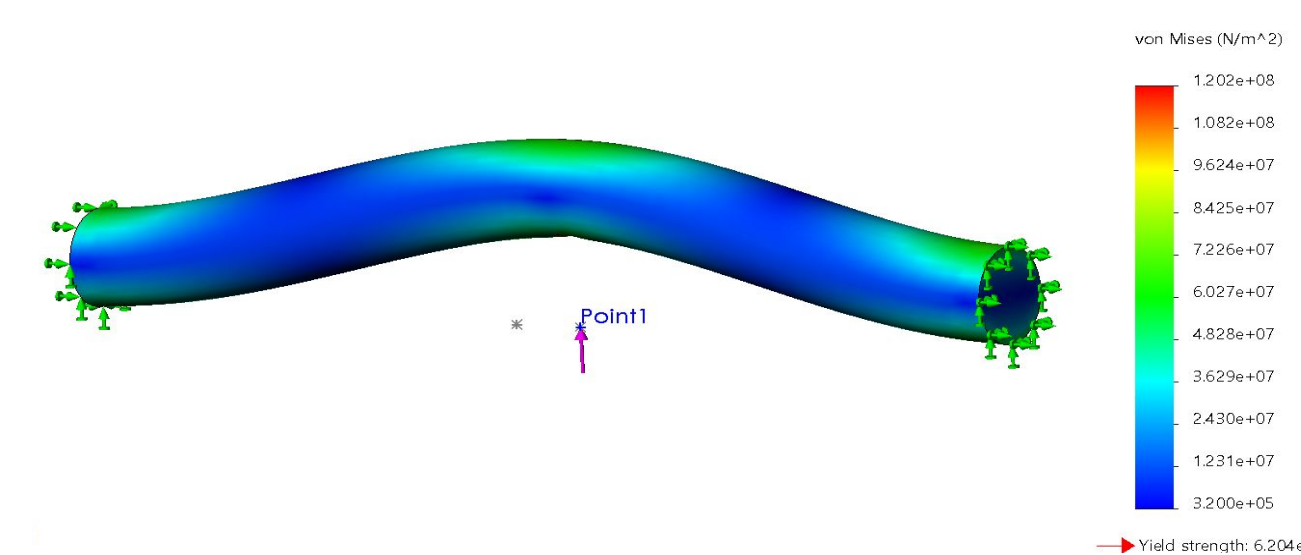
Cleaning ball valve components with isopropyl alcohol in ultrasonic cleaner.

Testing

- Modifying Ball Valves
 - $\frac{1}{8}$ " hole was drilled into closed side of ball to prevent pressure build up from propellant boil off within the ball.
 - The ball valves will cleaned/degreased of all OEM lubricant and Krytox will be reapplied to ensure compatibility with LOX.
 - Valve stem will be packed with teflon tape to ensure thermal contraction does not cause leakage through the valve stem interface.



- Initial Torque testing
 - Initial test on valve handle indicate between 3-5 ft-lbs of torque necessary to turn ball valve under standard day conditions.
- Static analysis of screw joint
 - Max. deflection of 0.002 mm
 - Max. stress of 17% of yield strength



Recommended Future Improvements

- Integrate sensors into final design to verify actuation
- Find a high pressure regulator that will convert 600psi to 150psi in order to provide more torque
- Optimize mounting claps for the valves
- integrate pneumatic solenoid and tubing into CAD Models
- Relocate pneumatic cylinder to underside of the mounting plate to reduce volume
- Add 5/16" through hole spacers between valve stem plates and clevis
- Add thrust washers to clevis and valve stem plates
- Add structural support to base plate to minimize deflection during actuation

Impact on Society

Low cost yet high performance liquid rocket systems such as MVAS, lower the barrier to entry to rocket systems for new engineers, start-ups, and future research endeavors. Making rocket systems more affordable will ultimately increase innovation and lead to growth in space exploration and commercial applications. The approach of this project is to produce a system that meets or exceed the reliability standards of off the shelf components at only a fraction of the cost.

Acknowledgments

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